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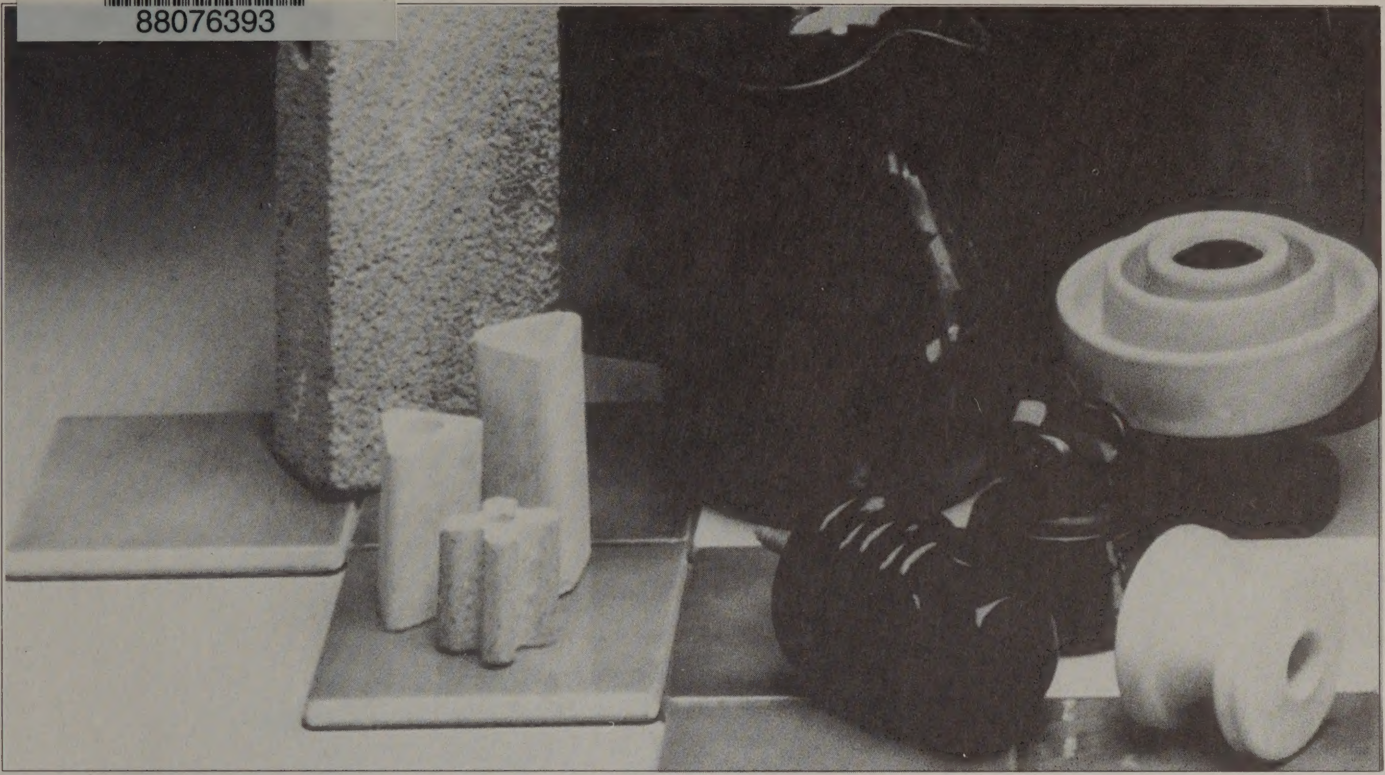

KYANITE AND RELATED MATERIALS

By Michael J. Potter

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KYANITE AND RELATED MATERIALS

MARCH 3, 1849

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Director

October 1991

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COVER PHOTO:
Although refractories are the major end use of kyanite, there are numerous other applications, such as kiln furniture, tile, pyrometer tubes, electrical insulators, shell castings, whiteware, etc. (Photo courtesy of R. T. Vanderbilt Co., Inc.)

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For comments or further information, please contact
The Branch of Industrial Minerals
The Division of Mineral Commodities
U.S. Bureau of Mines
2401 E St., NW, MS 5209
Washington, DC 20241-0001
Telephone: (202) 634-1185
Fax: (202) 634-4091

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KYANITE AND RELATED MATERIALS

By Michael J. Potter

Mr. Potter, a physical scientist with 24 years of industry and U.S. Bureau of Mines experience, has been the commodity specialist for kyanite since 1975. Domestic survey data were prepared by Joe Daniels, mineral data assistant; and international data table was prepared by Virginia Woodson, international data coordinator.

Kyanite, andalusite, and sillimanite are anhydrous aluminum silicate minerals of the same composition represented by the chemical formula $Al_2O_3 \cdot SiO_2$. Related materials include synthetic mullite, dumortierite, and topaz, also classified as aluminum silicates, although the last two additionally contain substantial proportions of boron and fluorine, respectively. The largest end use of kyanite group minerals and mullite is in the manufacture of high-alumina, high-performance refractories, including brick and shapes and monolithic refractory applications such as for high-temperature mortars or cements, ramming mixes, and castable refractories. U.S. production of kyanite was estimated to have decreased slightly compared with that of 1989 owing to flat or decreased activity in the iron and steel industry and other industries in which refractories were used. Domestic synthetic mullite output decreased compared with that of the previous year. Data have not been published to maintain company proprietary data. Imports of andalusite in 1990 were approximately 17,000 metric tons compared with the past few years when imports were in the 10,000-ton-per-year range.

DOMESTIC DATA COVERAGE

There are two known domestic kyanite mine-and-mill operations, but data are not known and would not be publishable because of company proprietary data. Of the three known synthetic mullite producers, all responded to the voluntary domestic survey. However, data cannot be published because of possible revealing of company proprietary data.

BACKGROUND

Definitions, Grades, and Specifications

Kyanite, andalusite, and sillimanite are a closely related trio of aluminum silicate minerals, differing slightly in physical properties and crystallographic characteristics, but sharing the same chemical composition, which can be represented as $A1_2O_3 \cdot SiO_2$. When heated, kyanite begins to break down to a noticeable extent at 1,315° C (andalusite at 1,382° C and sillimanite at 1,549° C) to form a mixture of mullite, $3Al_2O_3 \cdot 2SiO_2$, and vitreous silica, SiO_2. The mullite so produced usually consists of an aggregation of interlocking, acicular crystals and remains dimensionally and chemically stable until the temperature is raised to at least 1,810° C. These properties enable mullite to serve to advantage as a component in refractory shapes and furnace linings for a wide range of industrial applications. Above 1,810° C, mullite dissociates slowly with little change in volume into corundum (Al_2O_3) and silica, which recombine to form mullite at a lower temperature.

Topaz, $Al_2SiO_4(F,OH)_2$, and dumortierite, $Al_7(BO_3)(SiO_4)_3O_3$, are also often classed as members of the kyanite group of minerals. Upon firing, topaz loses fluorine and dumortierite loses boron, yielding refractory residues consisting essentially of mullite. A number of other substances—fire clay, siliceous bauxite, and kaolin, for example—owe their ability to perform satisfactorily in some refractory applications to the fact that, when heated, a least part of the aluminum silicate they contain is converted to mullite.

There are three types of synthetic mullite. Low-temperature sintered synthetic mullite is made by sintering siliceous bauxite or mixtures of bauxite and kaolin above 1,549° C. High-temperature sintered synthetic mullite is prepared by sintering mixtures of alumina and kaolin, bauxite and kaolin, or alumina, kaolin, and kyanite above 1,749° C. Fused synthetic mullite is made by melting Bayer process alumina and silica or bauxite and kaolin in an electric furnace at about 1,900° C.

All domestic kyanite ore is ground to permit separation and recovery by froth flotation of the mineral particles from accompanying gangue. The flotation-concentrate product is graded for sale to consumers in five particle-size ratings: 35, 48, 100, 200, and 325 mesh. Kyanite concentrates may contain from 56% to 60% alumina, from 38% to 44% silica, and from 0.2% to 0.9% iron oxide. Lump kyanite from India, ranging in size from pea to boulders, was formerly imported into the United States. Indian reserves are limited, however, and material is no longer being exported.

Products for Trade and Industry

Kyanite and related materials are consumed in the manufacture of high-alumina or mullite-class refractories and in lesser quantities as ingredients in ceramic compositions. U.S. kyanite is marketed either in raw form or after heat treatment as mullite. In the 35- to 48-mesh range, kyanite is used in monolithic refractory applications such as high-temperature mortars or cements, ramming mixes, and castable refractories or with clays and other ingredients in refractory compositions for making kiln furniture, insulating brick, firebrick, and a wide variety of other articles. More finely ground material, minus 200 mesh, is used in body mixes for sanitary porcelains, wall tile, investment-casting molds, and miscellaneous special-purpose ceramics.

Data on the properties of finished refractory products are available from the producing firms. However, selection of the best refractory available for a specific application can sometimes be made only by testing under actual operating conditions. Load-bearing capacity, slag resistance, spalling characteristics, and other factors are often of prime importance.

Zircon sand containing some kyanite, sillimanite, and/or staurolite is used for foundry and refractory sand.

Technology

Both mines of the one U.S. kyanite producer are open pit, hard-rock quarrying operations. Blasted material is reduced to manageable size by drop-ball breaking and trucked to the processing plants where it is crushed to minus 1-inch size in jaw and cone crushers and then ground in rod mills to minus 35 mesh or finer. Two stages of flotation with alkaline-fatty acid or acid-petroleum sulfonate collectors produce an intermediate kyanite concentrate, which after being freed from iron by high-intensity magnetic treatment, becomes a salable product. Some kyanite is calcined at about 1,593° C and sold as mullite.

Byproducts and Coproducts

Quartzitic waste tailings from kyanite concentrators may be marketed locally as construction sand, but transportation costs limit the shipping radius of this byproduct.

Andalusite occurs in pyrophyllite ores that are mined by a company for ceramic and refractory purposes in North Carolina. A zircon-refractory heavy-mineral sand produced in Florida contains a small amount of aluminum silicates (kyanite, sillimanite, and staurolite) and is used for foundry and refractory sand.

Substitutes

Substitute and alternative materials for kyanite-group and mullite products in refractories include fire clay, calcined bauxite, and alumina. Other materials such as magnesite, chromite, silicon carbide, and zircon are interchangeable for specific end uses and conditions. Local availability of refractory raw materials is an important factor in choosing refractory products because transportation costs may prohibit use of alternative technically superior materials.

ANNUAL REVIEW

Legislation

The allowable depletion rates for kyanite, established by the Tax Reform Act of 1969 and unchanged through 1990, were 22% for domestic production and 14% for foreign operations.

Issues

Andalusite continued to be imported into the United States in 1990 as one of several minerals and metals that were exempt under a section of the Comprehensive Anti-Apartheid Act. The exemption list included strategic minerals for which the quantities essential for the economy or defense of the United States were unavailable from reliable and secure suppliers.

Production

Kyanite was produced at two open pit mines by Kyanite Mining Corp.: the Willis Mountain and East Ridge Mines in Buckingham County, VA. The company also operated beneficiation plants and calcining facilities for conversion of kyanite to mullite.

High-temperature sintered mullite was produced by C-E Minerals Div. of Combustion Engineering Inc. at Americus, GA, and Didier Taylor Refractories Corp. at Greenup, KY. Electric-furnace-fused mullite was produced by Washington Mills Electro Minerals Corp. at Niagara Falls, NY.

C-E Minerals was sold to Imetal SA by Asea Brown Boveri Ltd. (ABB) of Switzerland after ABB purchased C-E's parent company, Combustion Engineering Inc.[1]

Consumption and Uses

The U.S. Bureau of Mines does not collect data on end uses of kyanite and synthetic mullite. However, refractories for the iron and steel industries were probably the major end use of kyanite-mullite, consuming an estimated 55% of the quantity produced. Nonferrous metallurgical operations were believed to be the next largest use, estimated at 20%. A third category, estimated at 15%, consisted of glassmaking furnaces, ceramic kilns, boilers, petroleum-processing equipment, etc. Nonrefractory uses were estimated to make up the remaining 10%.

In the iron and steel industries, mullite is important in critical areas of blast furnace stoves and stacks, reheat furnaces, steel degassing chambers and soaking pits, and many types of auxiliary pouring and handling equipment. In the nonferrous metal industry, an end-use example is in refractory linings of alumina reduction cells.

Other miscellaneous uses include kiln furniture, blown aluminum silicate high-temperature insulation, brake linings, foundry mold facings, glass additions for alumina contents, ceramic tile, pyrometer tubes, high-tension insulators, spinnable mullite fibers, shell castings, ceramic honeycomb, mortars, grinding media, whitewares, extrusion dies, and welding rod coatings.

Prices

Prices at yearend 1990, in British pounds, from Industrial Minerals (London) were unchanged from the previous year. Price increases for 1990 in table 1 represent a stronger British pound against the U.S. dollar than in 1989.

Foreign Trade

Shipments of U.S. kyanite, mullite, and synthetic mullite were believed to have been made to foreign destinations, including Europe and Asia. Imports of andalusite from the Republic of South Africa were 17,350 metric tons with a customs value of $2,805,000, according to the U.S. Department of Commerce.

World Review

Capacity.—Rated capacity is defined as the maximum quantity of product that can be produced in a period of time on a normally sustainable long-term operating rate, based on the physical equipment of the plant, and given acceptable routine operating procedures involving labor, energy, materials, and maintenance. Capacity includes both operating plants and

TABLE 1

PRICE OF KYANITE AND RELATED MATERIALS

(Dollars per metric ton)

	1989	1990
Andalusite, Transvaal, 57% Al_2O_3, bulk, c.i.f. main European port	144–160	171–190
Andalusite, Transvaal, 60% Al_2O_3, c.i.f. main European port	208	247
Sillimanite, South African, 70% Al_2O_3, bags, c.i.f. main European port	304	361
U.S. kyanite, 59% to 62% Al_2O_3, 35–325 Tyler mesh, raw and/or calcined, 18-ton lots, c.i.f. main European port	144–248	171–295
U.S. kyanite, f.o.b. plant, carlots:		
Raw	70–137	70–137
Calcined	123–172	123–172

Source: Industrial Minerals (London). Dec. 1989, No. 267, p. 75, and Dec. 1990, No. 279, p. 79.

TABLE 2

U.S. IMPORT DUTIES

Tariff item	No.	Most favored nation (MFN) Jan. 1, 1991	Non-MFN Jan. 1, 1991
Kyanite, sillimanite, andalusite, and dumortierite	2508.50	Free	Free
Mullite	2508.60	4.9% ad valorem	30% ad valorem

TABLE 3

WORLD KYANITE AND RELATED MINERALS CAPACITY, DECEMBER 31, 1990

(Thousand metric tons)

	Capacity
North America:	
United States:	
Kyanite	W
Synthetic mullite	W
Total	W
South America:	
Brazil: Kyanite[e]	5
Europe:	
France: Andalusite	60
Germany, Federal Republic of:	
Synthetic mullite[e]	10
Italy: Synthetic mullite[e]	5
Spain: Andalusite	5
Sweden: Kyanite	25
United Kingdom:	
Synthetic mullite	10
Other countries[e]	200
Total	315
Africa:	
South Africa, Republic of:	
Andalusite[e]	320
Sillimanite[e]	3
Zimbabwe: Kyanite	2
Total	325
Asia:	
China: Unspecified	3
India:	
Kyanite	38
Sillimanite	15
Total	56
Japan:	
Synthetic mullite[e]	30
Total	89
Oceania:	
Australia:	
Kyanite[e]	1
Sillimanite[e]	1
Total	2
World total[1] [2]	740

[e] Estimated. W Withheld to avoid disclosing company proprietary data.

[1] Excludes U.S. kyanite and synthetic mullite.

[2] Data do not add to total shown because of independent rounding.

plants temporarily closed that, in the judgment of the author, can be brought into production within a short period of time with minimum capital expenditure.

The data in table 3 are rated capacity for mines and refineries as of December 31, 1990. Capacity data for Japan, the Republic of South Africa, and Sweden were obtained from literature sources. For other countries, recent peak production or estimated production was considered to be equal to rated capacity.

China.—Although kyanite ore bodies usually contain only 15% to 20% kyanite, development and utilization of the mineral, as well as andalusite and sillimanite, has taken place in the past several years. Processing of kyanite minerals has been achieved by flotation and magnetic separation. Producers were working on improving product quality and finding opportunities to export abroad.[2]

A 3,000-ton-per-year andalusite plant began operation in Xixia County, Hunan Province. The andalusite source for the plant was a deposit with proven reserves of 7.8 million tons.[3]

India.—The Indian Bureau of Mines developed benefication steps to obtain refractory-grade kyanite from the country's low-grade, mica-quartz-bearing kyanite deposits. Ore reserves are 175 million tons, with 90 million tons in Bihar and 80 million tons in Andhra Pradesh. A representative sample from the Lapsoburu deposit, Singhbhum district, Bihar, contained an estimated 35% kyanite, 50% quartz, 10% mica, and 5% other minerals such as rutile, staurolite, iron oxides, amphiboles, etc. Two-stage froth flotation of the sample followed by wet high-intensity magnetic separation yielded a product containing about 95% kyanite, 1% quartz, 1% mica, and 3% other minerals with a kyanite recovery of 73%. Further research work successfully produced dense and volume-stable aggregates out of the beneficiated kyanite concentrate and thus established its suitability for making refractory brick.[4]

Ireland.—Navan Resources PLC continued with plans to obtain capital resources to conduct a full-scale evaluation and feasibility study of its Tomduff

TABLE 4

KYANITE: WORLD PRODUCTION, BY COUNTRY[1]

(Metric tons)

Country[2] and commodity	1986	1987	1988	1989	1990[e]
Australia:					
Kyanite	768	1,079	[e]500	[e]500	750
Sillimanite[3]	133	77	64	[e]70	100
Brazil: Kyanite	950	510	[e]1,000	[e]1,000	1,000
China: Unspecified[e]	2,500	2,500	2,500	2,500	2,500
France: Andalusite	50,900	50,000	[e]50,000	[e]50,000	50,000
India:					
Andalusite	732	122	—	—	—
Kyanite	32,394	39,959	[r]35,773	[r]39,489	39,000
Sillimanite	14,905	12,756	[r]15,377	[r]16,117	16,000
Kenya: Kyanite[e]	1	1	1	1	1
Korea, Republic of	[r]33	[r]85	[r]112	[r]19	20
South Africa, Republic of:					
Andalusite	181,466	194,373	259,556	[r]284,048	270,000
Sillimanite	1,330	1,243	781	[r]170	300
Spain: Andalusite	[r]3,304	[r]3,916	[r]3,360	[r] [e]3,500	3,600
Sweden: Kyanite[e]	5,000	5,000	5,000	5,000	5,000
United States:					
Kyanite	W	W	W	W	W
Mullite, synthetic[e]	W	W	W	W	W
Zimbabwe: Kyanite	1,851	1,834	1,795	[r]1,869	1,800

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.

[1]Owing to incomplete reporting, this table has not been totaled. Table includes data available through Apr. 2, 1991.

[2]In addition to the countries listed, a number of other nations produce kyanite and related materials, but output is not reported quantitatively, and no reliable basis is available for estimation of output levels.

[3]In addition, about 7,000 metric tons of sillimanite clay (also called kaolinized sillimanite) is produced annually containing 40% to 48% Al_2O_3.

andalusite project in County Carlow. Initial studies revealed a mineralized zone 5 kilometers by 200 meters to 300 meters with a 9% to 25% andalusite content. The company believed that the property could support a production capacity of 50,000 tons per year producing a material 2.8 millimeters to 10 millimeters.[5] In late 1990, Navan announced taking a Swiss joint-venture partner, Realstate AG, to continue the evaluation of the andalusite project.[6]

OUTLOOK

The iron and steel industry has been the dominant consumer of refractories, including those based on kyanite and mullite. Steel output has been static in some countries but has shown growth in other regions such as China and Latin America.[7] In Eastern Europe, the refractories in use are the cheaper, less efficient fireclays. This region may be a potential growth market for conversion to alumino-silicate refractories, which have a higher alumina content and are more efficient.[8]

More severe operating conditions in iron and steel and other industries have required refractories that give longer service life. This has resulted in a reduction in overall refractory consumption. However, kyanite usage has been stable because of newer and more recent applications and uses.[9]

OTHER SOURCES OF INFORMATION

Bureau of Mines Publications

Kyanite and Related Materials. Ch. in Minerals Yearbook, annual.

Kyanite and Related Minerals. Ch. in Mineral Commodity Summaries, annual.

Minerals Today, bimonthly.

Other Sources

Bennett, P. J., and J. E. Castle. Kyanite and Related Minerals. Ch. in Industrial Minerals and Rocks. American Institute of Mining, Metallurgical, and Petroleum Engineers, New York, 5th ed., 1983, pp. 799–807.

Dickson, T. Sillimanite Minerals. Metals & Minerals Annual Review—1990, June 1990, pp. 98–99.

Varley, E. R. Sillimanite (Andalusite, Kyanite, Sillimanite). Chemical Publishing Co. Inc., New York, 1968, 165 pp.

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[1]Chemical Marketing Reporter. ABB Plans Sale of C-E Minerals Unit. V. 237, No. 22, p. 27.

[2]Guanghuan, W. Chinese Resources and Processing Technology for Kyanite Minerals. Ind. Miner. (London), No. 270, Mar. 1990, pp. 95, 97, 98.

[3]Industrial Minerals (London). Mineral Notes. No. 275, Aug. 1990, p. 61.

[4]Amanullah, S., G. M. Rao, and K. Satyanarayuna. Beneficiation of Mica-Quartz-Bearing Kyanite. Paper in Processing Developments (Proc. 9th "Ind. Min." Int. Congr., Sydney, Australia, Mar. 25–28, 1990). Met. Bull. J., 1990, pp. 24–25, 27–29.

[5]Industrial Minerals (London). Fillers and Extenders. No. 277, Oct. 1990, p. 97.

[6]———. World of Minerals. No. 279, Dec. 1990, p. 9.

[7]Roskill Information Services Ltd. (London). The Economics of Kyanite Group Minerals 1990, 6th ed., 110 pp.

[8]McMichael, B. Alumino-Silicate Minerals. Ind. Miner. (London), No. 277, Oct. 1990, p. 43.

[9]Kay, C. Kyanite. Min. Eng., v. 42, No. 6, June 1990, pp. 566-567.

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